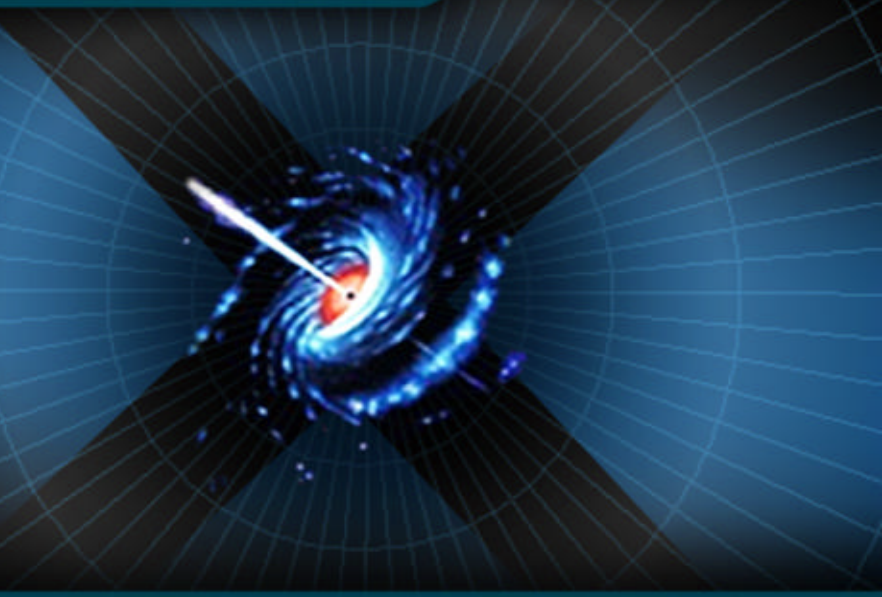
Constellation-X Facility Science Team Meeting — Nov. 19, 2003

Constellation-X
The Constellation X-ray Mission



SXT and FMA Status

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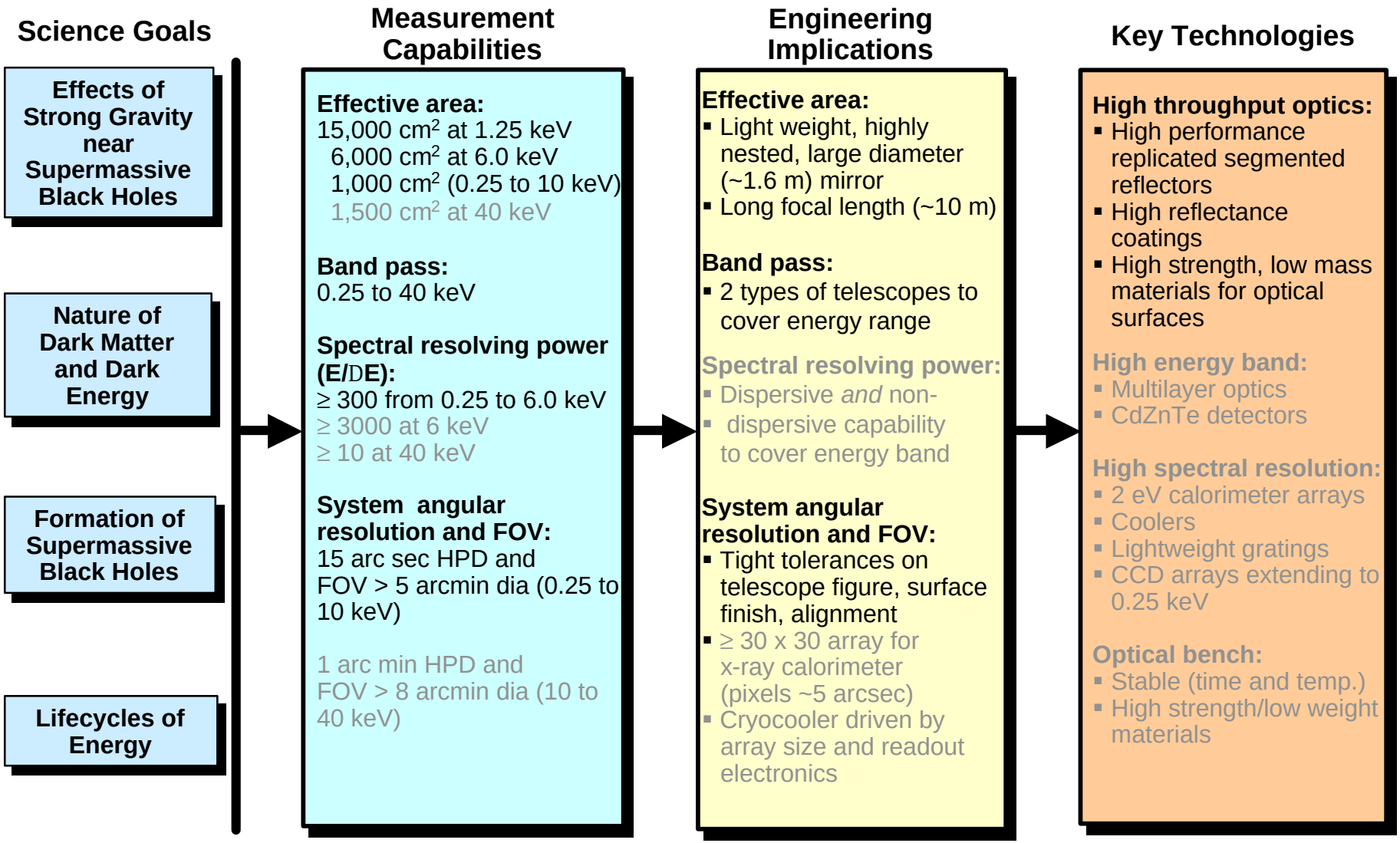
NASA

Outline

- SXT status - R. Petre
  - Requirements update
  - Reference design
  - Technology roadmap
  - Recent accomplishments
  - Plans for coming year
  - FMA industry study
- Reflector development - W. Zhang
- SXT Metrology - D. Content
- OAP “dry run” at MSFC - W. Jones

Constellation-X Mission Requirements Flow Down



Mission Performance Requirements

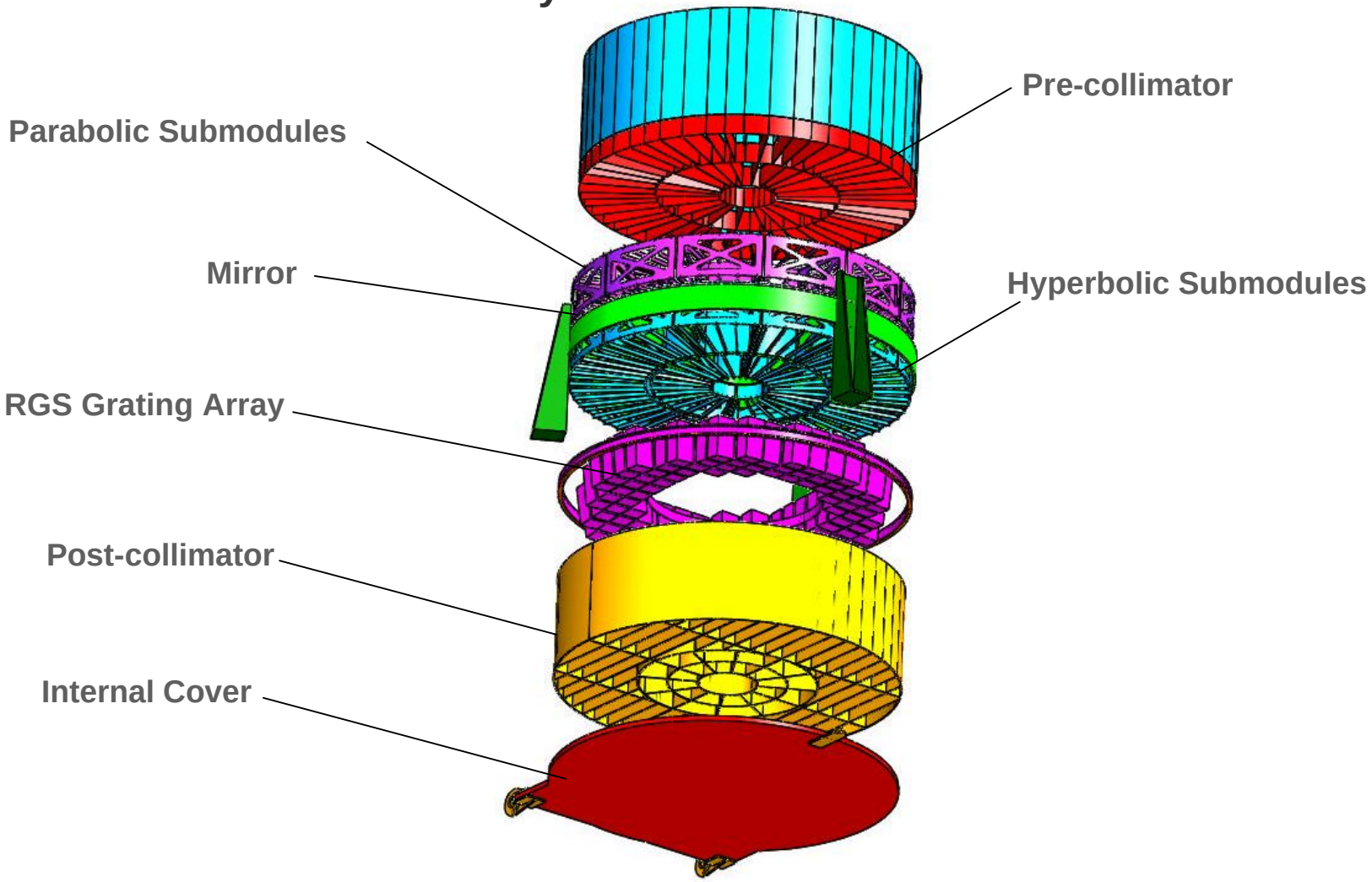
- **Mission science performance requirements:**
  - **Mission level effective areas from 0.25 to 10 keV**
    - **Based on instantaneous observing requirements for time dependent phenomena**
  - **Angular resolution**
    - **Direct requirement based on confusion limit**
    - **RGA requirement for spectral resolving power has an implicit requirement on SXT mirror**
    - **These coincidentally result in 12.5 arcsec each for FMA**
  - **Mission level field of view (FOV)**
    - **Limited in practice by the detectors, not the optics**
    - **But places limits on FMA optical path internal alignments**
  - **Stray light**
    - **Based on low flux source sensitivity and detector background considerations**

SXT Performance Requirements and Goals

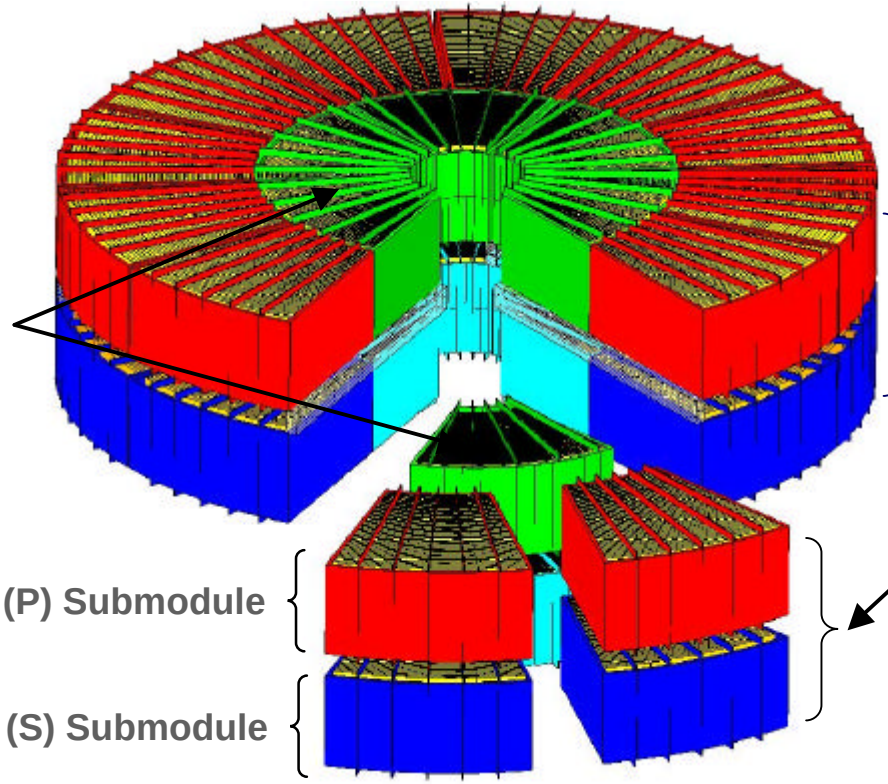
- **Effective area**
  - Increased to offset reduce grating efficiency prediction and blockage of mirror structures
  - 9630 cm^2 at 0.25 keV
  - 7250 cm^2 at 1.25 keV
  - 1730 cm^2 at 6 keV
  - 380 cm^2 at 10 keV
  - Goal is to maximize margin over requirement
- **On-axis angular resolution on-orbit (unchanged)**
  - Requirement: 12.5 arcsec Half Power Diameter (HPD)
  - Goal: 4 arcsec HPD
  - Need more complete specification - 70 % and/or 90 % encircled energy diameter
- **Field of view**
  - Was specified as 2.5 arc minute diameter
  - Increased to accommodate square calorimeter array
  - Effective area at 2.5 arc minutes off axis is >95 percent of on-axis effective area (at 1.25 keV)
- **Stray light rejection (new)**
  - Photon flux from source outside field of view is $=10^{-3}$ of on-axis flux

SXT Flight Mirror Assembly (FMA) Reference Concept

- 1.6M Diameter FMA Assembly



FMA Reference Concept Mirror Incorporates Modular Approach



Inner Modules (6)
(Shells 104 to 230)

2x20 cm mirror
length (plus gap)

Outer Modules (12)
(Shells 1 to 89)

Outer Primary (P) Submodule

Outer Secondary (S) Submodule

1.6 m Diameter at P-S Intersection

FMA Reference Concept Mirror Design Parameters

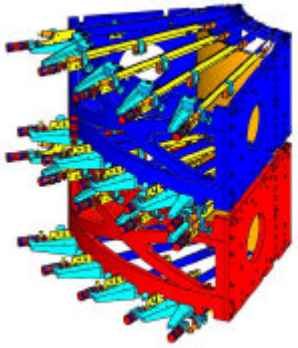
Parameter	Description
Design	Segmented Wolter I
Reflector substrate material	Thermally formed glass
Reflecting surface fabrication	Epoxy replication
X-ray reflecting surface	Gold
Number of nested shells	127 (inner); 89 (outer)
Total number of reflectors	3660
Reflector length	20 cm
Number of modules	6 (inner); 12 (outer)
Module housing composition	Titanium alloy, CTE-matched to substrate
Largest reflector surface area	0.08 m^2
Reflector substrate density	2.4 gm/cm^3
Reflector thickness	0.41 mm
Reflector microroughness	0.4 nm RMS
FMA mechanical envelope	1.68 m dia x 1.98 m

Segmented X-ray Mirror Development Process

	Optical Assembly Pathfinder		Engineering Unit	Mass Production Pathfinder	Prototype Pathfinder	Prototype
	OAP #1	OAP #2				
Configuration						 Industry Development
Module Type	Inner	Inner	Inner	Inner	Outer	Sector (2 Outer & 1 Inner)
Housing Material	**Aluminum**	**Titanium**	Titanium/composite	Titanium/composite	Titanium/composite	Titanium/composite
Focal Length	8.4 m	8.4 m	8.4 m	8.4 m	10.0 m	10.0 m
Reflector Length (P&S)	2 x 20 cm	2 x 20 cm	2 x 20 cm	2 x 20 cm	2 x 20-30 cm	2 x 20-30 cm
Nominal Reflector Diameter(s)	50 cm	50 cm	50 cm±	50 cm±	160 cm± 120 cm± 100 cm	160 cm± 120 cm± 100 cm± 80cm±, 30 cm±
Goals	▪ Align 1 reflector pair (P&H) ▪ Evaluate mirror assembly design, alignment and metrology	▪ Align 1 reflector pair ▪ Evaluate reflector ▪ Evaluate mirror bonding ▪ X-ray test	Requirements: ▪ Align one reflector pair to achieve <12.5 arcsec ▪ X-ray test, vibration test (Q4 of FY04) Goals (Q2 of FY05): ▪ Replicate 3 mirror pairs using a single replication mandrel ▪ Align up to 3 reflector pairs to achieve <12.5 arcsec ▪ Environmental test	▪ Align 3 reflector pairs ▪ Evaluate tooling and alignment techniques for mass production ▪ X-ray test	▪ Flight-like configuration outer module ▪ Environmental and X-ray test ▪ Largest reflectors	▪ Demonstrate largest and smallest diameter reflectors ▪ Demonstrate module to module alignment ▪ Environmental and X-ray test
TRL	TRL 3		TRL 4		TRL 5/6	TRL 6
Timeframe	Q2 of FY03	Q3 of FY04	Q2 of FY05	Q4 of FY05	Q2 of FY07	Q3 of FY07
Technology Gate			◆		◆	

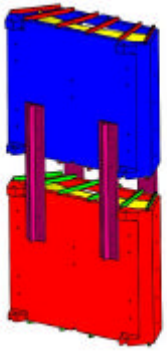
SXT Mirror Phased Technology Development

OAP 1



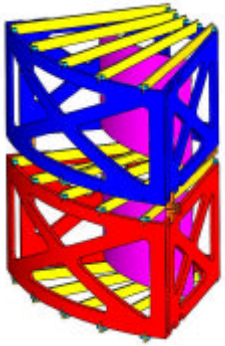
Inner Module (P&S)
Objective: Evaluate mirror assy design, alignment and metrology

OAP 2



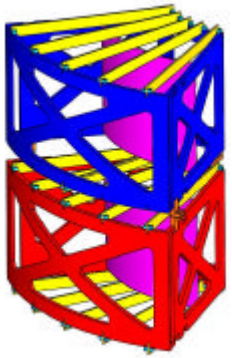
Inner Module (P&S)
Objective: Evaluate reflector, mirror bonding

Engineering Unit (EU)



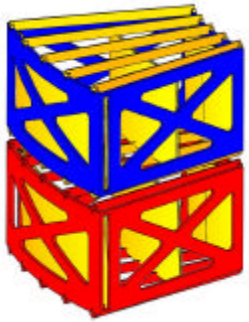
Inner Module (P&S)
Objective: Evaluate assembly gravity sag, titanium housing, X-ray and environmental test

Mass Alignment Pathfinder



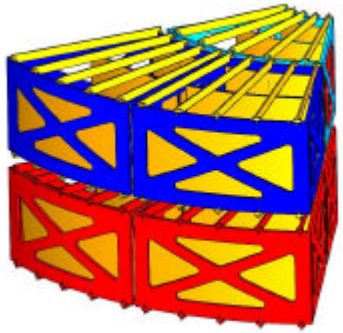
Inner Module (P&S)
Objective: Evaluate tooling and alignment techniques for mass production, X-ray test

Prototype Outer Pathfinder



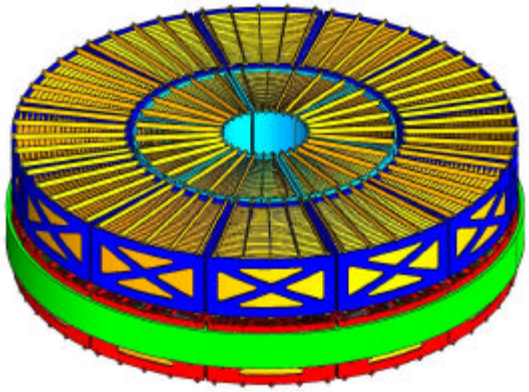
Outer modules (P&S) Largest Reflectors
Objective: Evaluate flight-like configuration outer module, X-ray and environmental test

Prototype Unit



Two outer modules + one Inner module (P&S)
Objective: Evaluate flight-like subassembly, X-ray and environmental test

Flight Mirror Assembly (FMA)



SXT Technology Development — Status

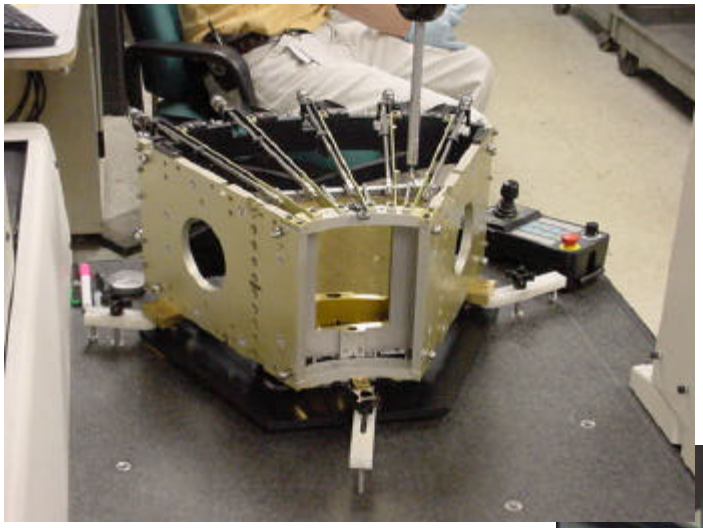
- Development has centered on 50 cm diameter engineering testbeds with 8.4 m focal length
  - Utilizes available metal mandrels and preparation facilities (coating & cleaning)
- Substantial progress toward making 50 cm diameter reflector segments that meet requirements (Will Zhang presentation)
  - Reflector fabrication is key issue to meeting angular resolution requirement
  - Fabrication of acceptable reflectors requires accurately figured forming mandrels
    - Reflector quality is now limited by forming mandrel quality
    - Forming and replication require dust-free environment
  - Modified epoxy application approach - applied as axial strips; reduction of thickness
  - Knowledge of reflector quality is currently limited by ability to mount reflectors for metrology
    - Low stress mounts are yielding reproducable measurements
    - Still lack ability to map free standing reflector in three dimensions
- Forming mandrel requirements (figure, material) evolving along with reflector production process; 50 cm mandrels being modified to meet new requirements
- Replication mandrels fabricated by Zeiss meet figure requirements (not goal)
- OAP1 work demonstrated ability to reproducibly manipulate and align reflectors
- OAP2 used to develop reflector bonding scheme
- OAP2 “dry run” carried out to prepare for X-ray performance tests in MSFC Stray Light Facility (Bill Jones presentation)
- Status summarized in 2003 SPIE papers

Precision forming and replication mandrels

- Con-X has taken delivery from Zeiss of three precision (~4") Zerodur replication mandrels for 30-degree arcs of 1.6 m 1.2m, and 1.0 m diameter mirrors.
- Schott is producing a precision Keatite (Zerodur K20) forming mandrel for the 1.6 m secondary. A fused Si forming mandrel for the primary will be figured to higher accuracy by Zeiss.
- Figure of all forming mandrels must be made more accurate than previously thought .
- Forming mandrel material under study. Fused Si is acceptable; SXT will determine acceptability of Zerodur K20.
- Cylindrical, fused Si 50 cm forming mandrels are being accurately figured (to 2-4") by GSFC optics branch (completion by January 2004). Precision 50 cm "slab" forming mandrels will be procured.

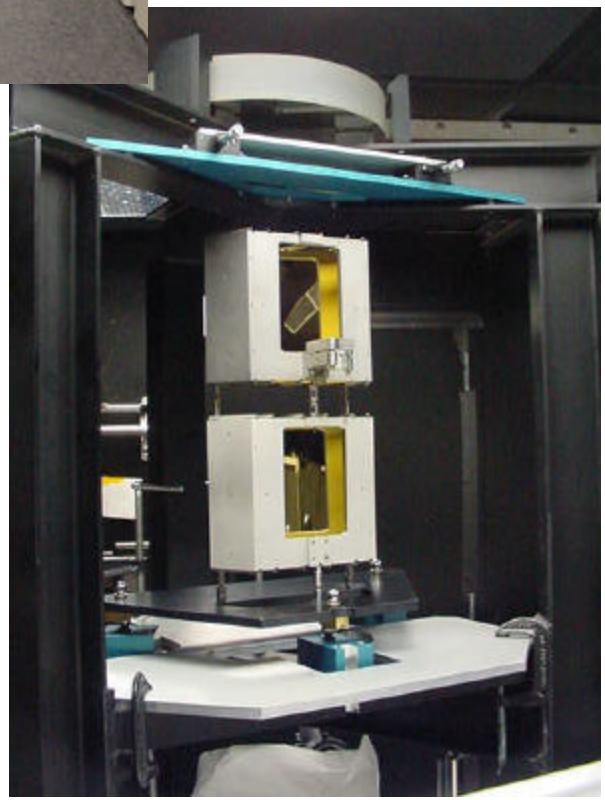
Alignment Housings

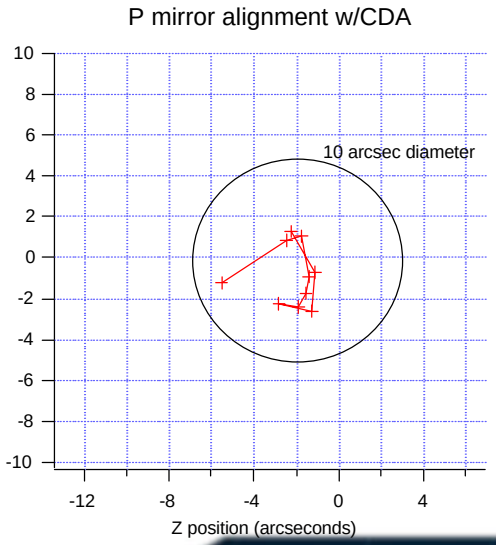
- Work up until now has concentrated on individual thin glass reflector behavior under the constraints of the Optical Alignment Pathfinder (OAP1 and OAP2) systems
- OAP1 designed to hold a reflector and adjust it at multiple points along the top and bottom of the reflector
- OAP2 designed to provide a low stress housing that can hold a reflector bonded in place. It can be used in vertical or horizontal orientation without imparting significant deformation on the reflector
- Each allow the use of CDA and front surface axial interferometry
- Future generation housings will incorporate characteristics that allow for mass alignment



OAP1

OAP2





Technology Goals for Coming Year

- **Continue improving 50 cm diameter reflector figure - key to success**
  - Refinement of forming - more uniform temperature
  - Obtain forming mandrels with 2 - 4 arcsec figure
  - Reduce epoxy thickness
  - Develop means of 3D mapping of free standing reflector
- **X-ray and environmental tests of reflector pair (in OAP2 housing)**
- **Design and start construction of Engineering Unit**
  - Current design details carried in reference mechanical design
- **Develop automated alignment scheme**
  - Incorporate CDA measurements into computer-controlled feedback loop for reflector alignment
- **Upgrade facility for producing 1.6 m diameter reflectors**
  - Replication and coating chambers have been ordered
- **Support Flight Mirror Array industry study**
  - Produce requirements and reference documents, and statement of work
  - Support selection process
  - Interact with selected contractors

FMA Overall Acquisition

- SXT FMA is longest lead item for Constellation-X mission
- Phase A FMA study contracts starting Q3 FY04
  - FMA System Study (Multiple Awards ~ 6/04)
  - Reflector Production Study (Multiple Awards ~11/04)
- FMA contract award Q4 FY05 will include
  - Final prototype technology demonstration
    - Technology transfer
  - Four FMA's
    - Reflector production included
    - Mandrels may be GFE or included
    - Grating modules or assembly will be GFE (competed under Announcement of Opportunity)
- FMA deliveries to Observatory Q2 FY12 – Q3 FY13
  - FMA qualified and calibrated upon delivery

Objectives of FMA System Study Contract

- Begin FMA technology and systems knowledge transfer to potential industry FMA providers
- Develop an FMA design
- Provide input to and feed back on specifications at various levels
  - Technology development program specifications
  - Preliminary production specifications for Reflector Production Study contract
  - Reflection Grating Spectrometer interfaces
  - Observatory level specifications
- Develop strategies for FMA technology transfer
- Identify final stage(s) of FMA prototype
- Provide input in preparation for FMA flight procurement
  - Requirements and Interface definition
  - Cost and schedule ROM's